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Topology Optimisation for Coupled Convection Problems

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Abstract

The work focuses on applying topology optimisation to forced and natural convection problems in fluid dynamics and conjugate (fluid-structure) heat transfer. To the authors' knowledge, topology optimisation has not yet been applied to natural convection flow problems in the published literature and the current work is thus seen as contributing new results to the field. In the literature, most works on the topology optimisation of weakly coupled convection-diffusion problems focus on the temperature distribution of the fluid, but a selection of notable exceptions also focusing on the temperature in the solid are [3–6].

The developed methodology is applied to several two-dimensional solid-fluid thermal interaction problems, such as cooling of electronic components and heat exchangers, as well as to the design of micropumping devices based on natural convection effects.

The implementation utilises the widely used Brinkman-penalisation approach to fluid topology optimisation [2] combined with suitable interpolation functions for thermal conductivity. The Method of Moving Asymptotes (MMA) is used and density filtering is applied in order to ensure a minimum lengthscale. The results are generated using stabilised finite elements implemented in a parallel multiphysics analysis and optimisation framework DFEM [1], developed and maintained in house.

Focus is put on control of the temperature field within the solid structure and the problems can therefore be seen as conjugate heat transfer problems, where heat conduction governs in the solid parts of the design domain and couples to convection-dominated heat transfer to a surrounding fluid. Both loosely coupled and tightly coupled problems are considered. The loosely coupled problems are convection-diffusion problems, based on an advective velocity field from solving the isothermal incompressible Navier-Stokes equations. The tightly coupled problems are natural convection problems, where the Boussinesq approximation has been applied to couple the temperature and velocity fields both ways. All of the considered flows are assumed to be laminar and steady.

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